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(54) **ROTOR OF ROTARY ELECTRIC MACHINE**

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**Masashi Inoue**, Wako (JP)

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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**Related U.S. Application Data**

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(57) **ABSTRACT**

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(52) **U.S. Cl.**  
CPC ..... **H02K 1/276** (2013.01); **H02K 2213/03** (2013.01)

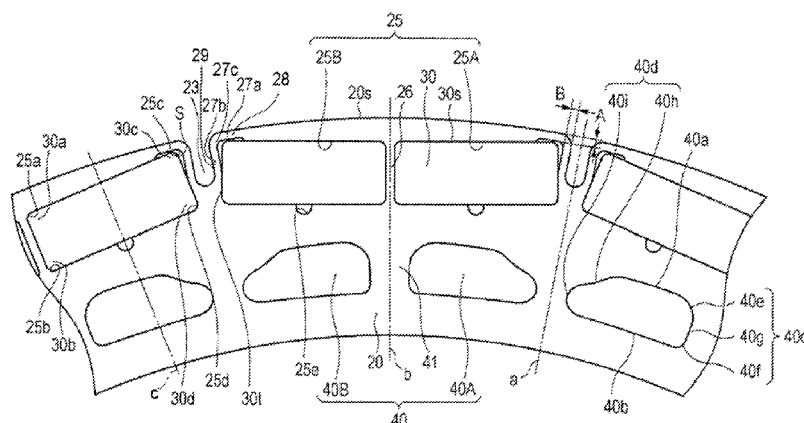
(58) **Field of Classification Search**

CPC ..... H02K 1/276  
USPC ..... 310/156.01, 156.36–156.3, 310/156.43–156.58, 8

See application file for complete search history.

A rotor of a rotary electric machine includes a rotor core, a plurality of magnet groups, and a plurality of grooves provided between adjacent slot groups. A circumferential rib is provided at a first position on an outer circumferential surface of each of the magnets. A radial direction rib is provided at a second position on a circumferential direction surface of each of the magnets. A curved rib connects the circumferential rib and the radial direction rib, and has an inner surface and an outer surface both being curved in an circular arc shape. The circumferential rib, the curved rib, and the radial direction rib are spaced apart from the outer circumferential surface, the outer circumferential corner, and the circumferential direction surface of each of the magnets.

**17 Claims, 4 Drawing Sheets**



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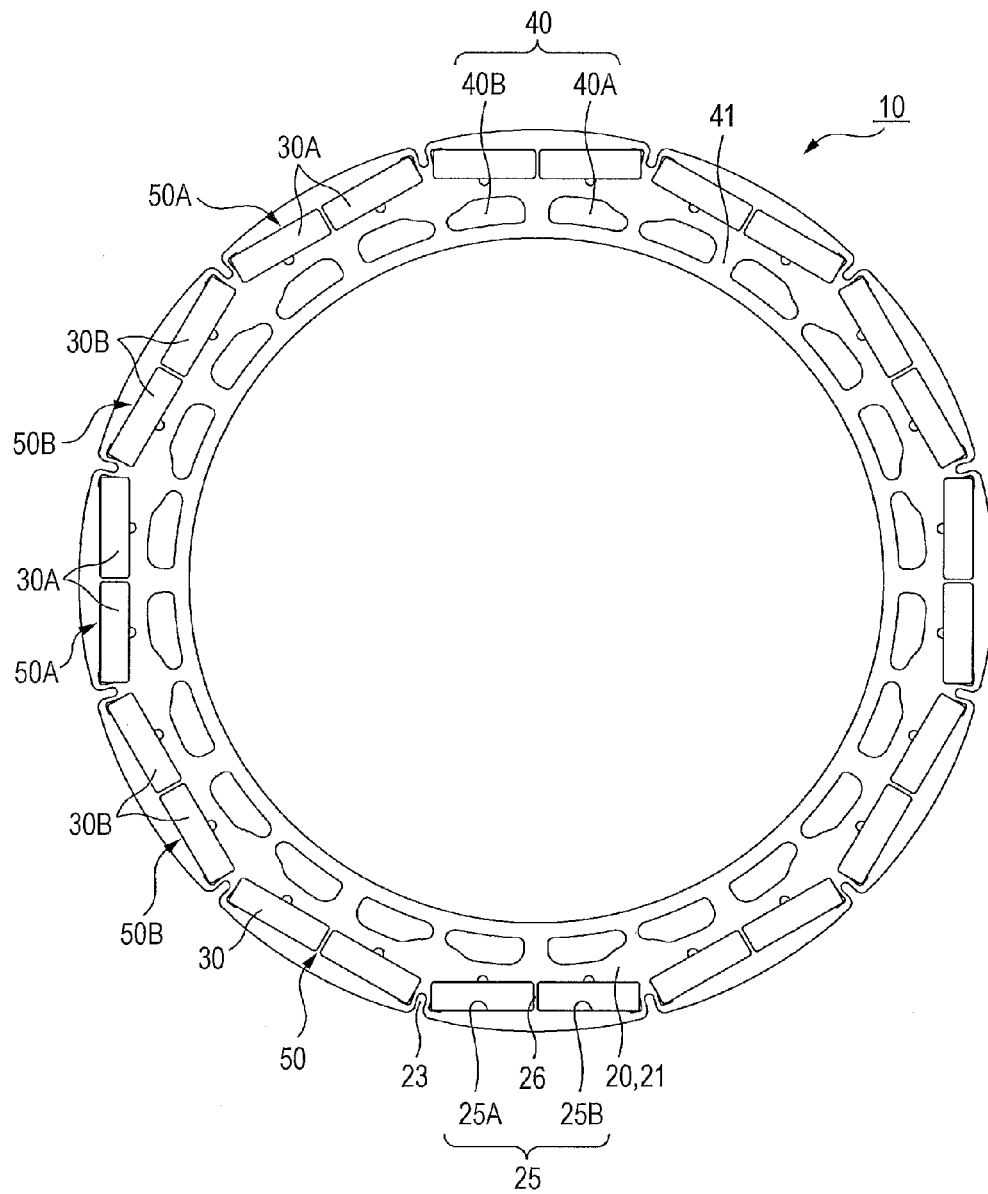
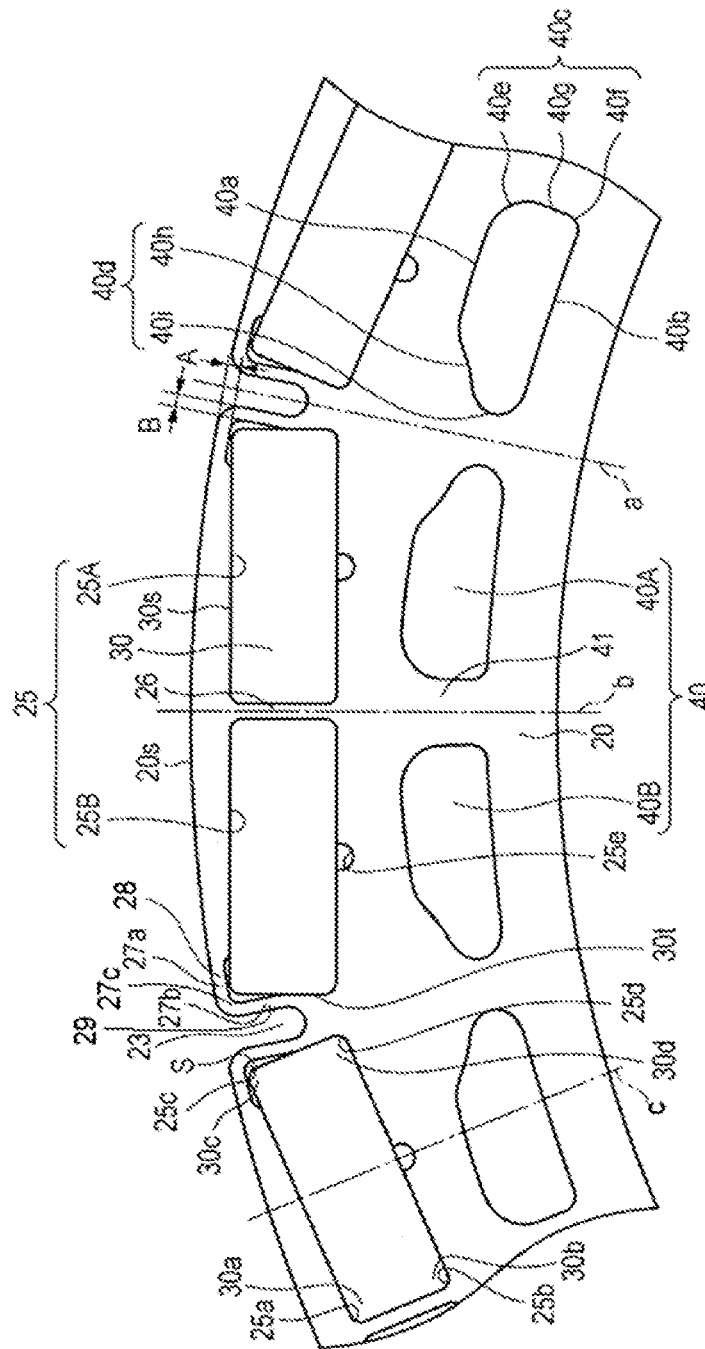


FIG. 2



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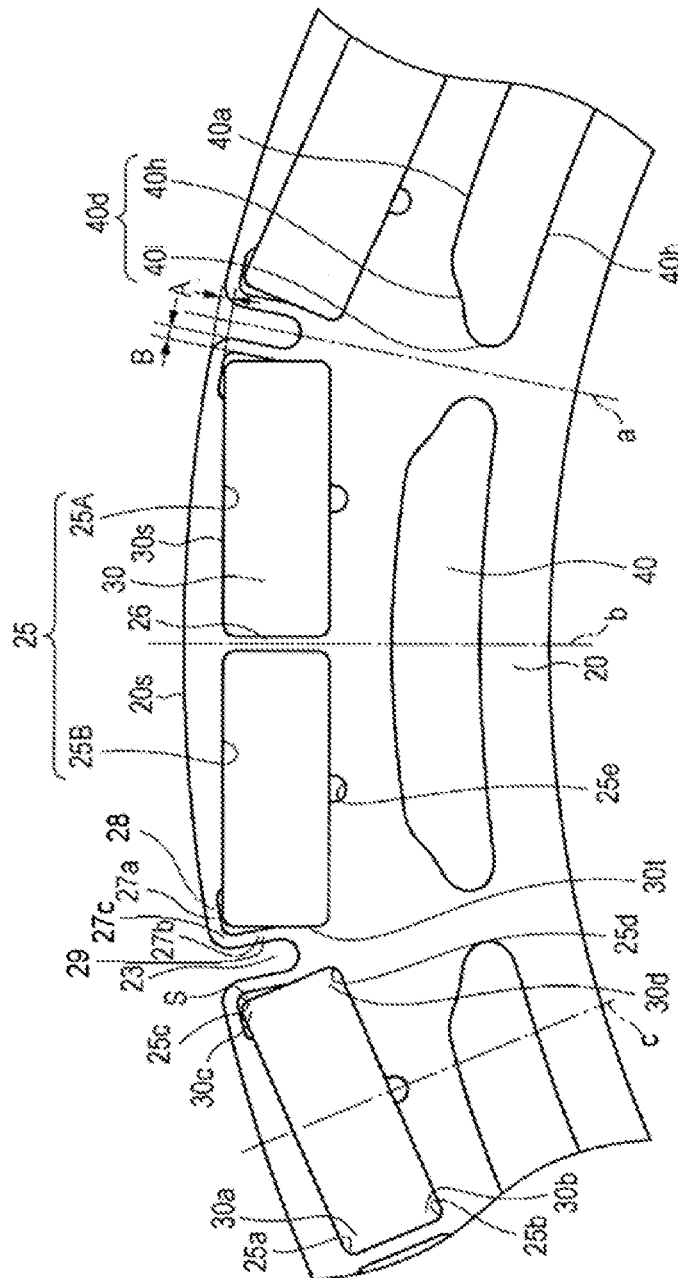
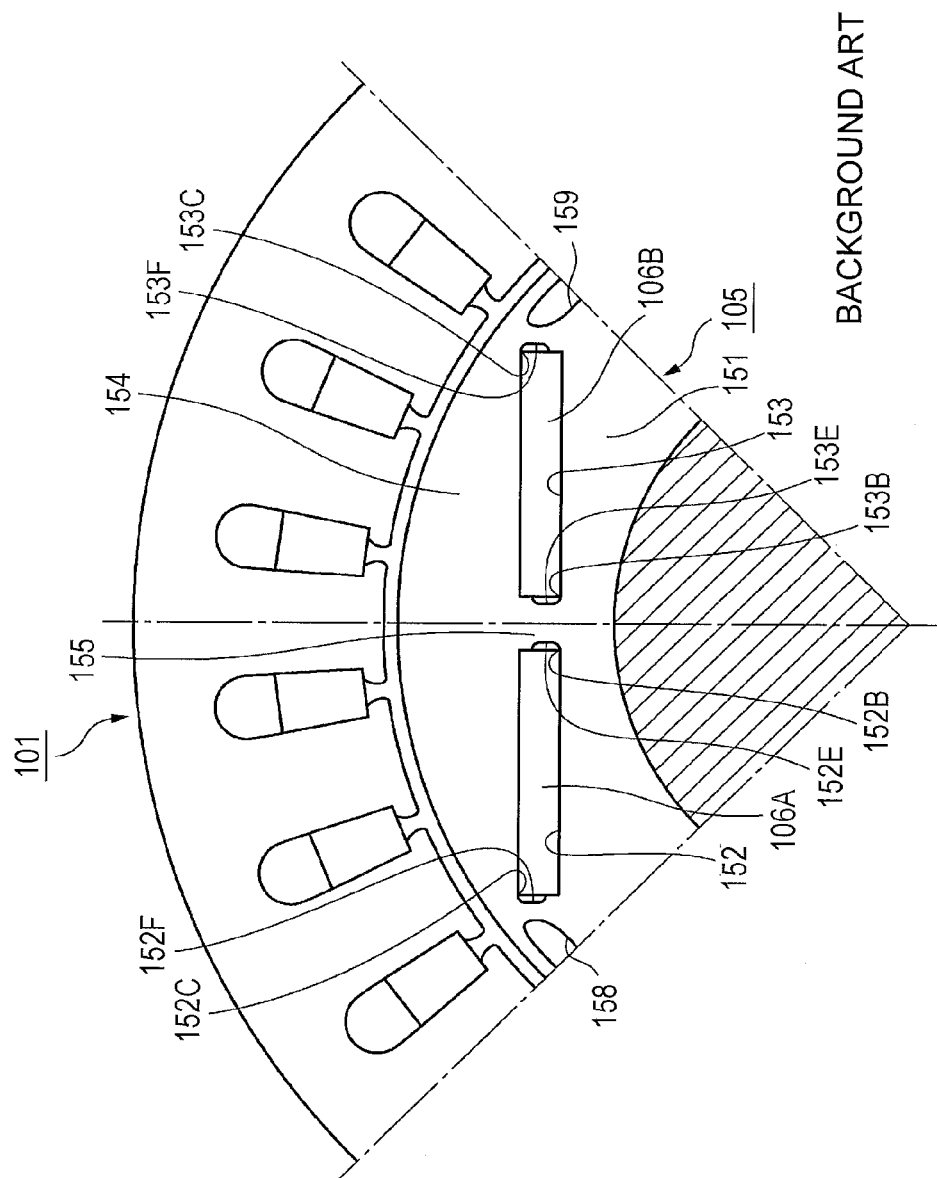


FIG. 4



# **ROTOR OF ROTARY ELECTRIC MACHINE**

## **CROSS-REFERENCES TO RELATED APPLICATIONS**

The present application is a continuation application of U.S. patent application Ser. No. 13/283,591 filed Oct. 28, 2011, which claims priority under 35 U.S.C. §119 to Japanese Patent Application No. 2010-245626 filed Nov. 1, 2010, entitled "Rotor of Rotary Electric Machine." The contents of these applications are incorporated herein by reference in their entirety.

## **BACKGROUND OF THE INVENTION**

### **1. Field of the Invention**

The present invention relates to a rotor of a rotary electric machine.

### **2. Discussion of the Background**

A known rotor of a rotary electric machine includes a rotor core, which is constituted of multi-layered annular steel plates and has slots, each in which a permanent magnet is disposed (for example, refer to Japanese Patent No. 4244111).

As illustrated in FIG. 4, a rotor **105** of a rotary electric machine according to Japanese Patent No. 4244111 includes a rotor core **151**, which is constituted of limited electromagnetic steel plates disposed inside an armature **101**; through-holes **158** and **159** formed in both wing parts; rectangular slots **152** and **153**, which are interposed between the through-holes **158** and **159** and separated by a center part of the rotor core **151**; permanent magnets **106A** and **106B** fit into the slots **152** and **153**, respectively; a protruding pole part **154** disposed on the upper surfaces of the permanent magnets **106A** and **106B**; and a bridge (center rib) **155** connecting the protruding pole part **154** and the rotor core **151** between the slots **152** and **153**. Stepped parts **152E** and **153E**, which protrude toward the bridge **155**, are disposed on inner circumferential corners **152B** and **153B** on the bridge **155** sides of the slots **152** and **153**, and stepped parts **152F** and **153F**, which protrude in a direction opposite to the bridge **155**, are disposed on outer circumferential corners **152C** and **153C** on the opposite side of the bridge.

With the rotor **105** having the above-described configuration, by disposing the stepped parts **152E** and **152F**, **153E**, and **153F** in the slots **152** and **153**, stress concentration due to a centrifugal force can be dispersed at the corners **152B**, **152C**, **153B**, and **153C** of the slots **152** and **153** while rotating at high speed.

## **SUMMARY OF THE INVENTION**

According to one aspect of the present invention, a rotor of a rotary electric machine includes a rotor core. The rotor core includes a center axis, multiple layers of electromagnetic steel plates, and a plurality of slot groups adjacent to each other in a circumferential direction of the rotor core, the plurality of slot groups each comprising slots. A plurality of magnet groups each includes magnets provided in the slots respectively. The plurality of magnet groups are adjacent to each other in the circumferential direction such that directions of magnetic poles of the adjacent magnet groups are opposite. Each of a plurality of grooves is provided between adjacent slot groups of the plurality of slot groups on an outer circumferential surface of the rotor core. Each of the plurality of grooves has an innermost diameter which is a distance from the center axis of the rotor core to an innermost portion

of each of the plurality of grooves. The innermost diameter is smaller than an outermost diameter of each of the magnets which is a distance from the center axis of the rotor core to an outermost portion of each of the magnets. A circumferential rib is provided at a first position on an outer circumferential surface of each of the magnets. The first position is closer to a pole center than to an outer circumferential corner of each of the magnets. The outer circumferential corner is located at the outer circumferential surface of each of the magnets. The circumferential rib extends from the first position in the circumferential direction while being spaced apart from the outer circumferential surface and the outer circumferential corner of each of the magnets. A radial direction rib is provided at a second position on a circumferential direction surface of each of the magnets. The second position is further radially inward than the outer circumferential corner each of the magnets. The radial direction rib extends from the second position in a radial direction of the rotor core and between each of the grooves and the circumferential direction surface of each of the magnets while being spaced apart from the circumferential direction surface and the outer circumferential corner of each of the magnets. A curved rib connects the circumferential rib and the radial direction rib, and has an inner surface and an outer surface both being curved in an circular arc shape. The circumferential rib, the curved rib, and the radial direction rib are spaced apart from the outer circumferential surface, the outer circumferential corner, and the circumferential direction surface of each of the magnets.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings.

FIG. 1 is a front view of a rotor according to an embodiment of the present invention.

FIG. 2 is a partially enlarged view of the rotor in FIG. 1.

FIG. 3 is a partially enlarged view of a rotor according to a reference example, which does not include a reinforcement rib.

FIG. 4 is a front view of essential parts of a known rotor.

## **DESCRIPTION OF THE EMBODIMENTS**

The embodiments will now be described with reference to the accompanying drawings, wherein like reference numerals designate corresponding or identical elements throughout the various drawings.

A rotor of a rotary electric machine according to an embodiment of the present invention will be described in detail below with reference to FIGS. 1 and 2. The drawings are viewed in the direction corresponding to the reference numerals.

A rotor **10** of a rotating electric machine according to this embodiment is disposed on the inner circumferential side of a stator (not shown) and includes a rotor core **20** that is attached to the outer circumferential side of a substantially cylindrical rotor shaft (not shown), which is a rotary shaft, and magnetic parts **50** disposed inside the rotor core **20** along the circumferential direction at equal intervals.

The rotor core **20** includes multiple layers of annular electromagnetic steel plates of substantially the same shape, e.g., silicon steel plates **21**. The outer circumference of the rotor core **20** has substantially U-shaped grooves **23** provided at predetermined intervals. Rectangular slots **25**, i.e., each

including first and second sub-slots **25A** and **25B**, are interposed between adjacent grooves **23**.

A center rib **26** separates each of the slots **25** into the first sub-slot **25A** and the second sub-slot **25B**, which are substantially symmetrically about the center rib **26**, and extends in the radial direction at the circumferential middle area of the slot **25**.

The magnetic parts **50** are magnetized in the radial direction such that opposite poles alternate along the circumferential direction. Each magnetic part **50** includes a pair of permanent magnets **30** placed inside the slot **25**. Specifically, the pair of permanent magnets **30** is placed inside the slot **25** such that, when the outer circumferential side of a magnetic part **50A**, which is constituted of a pair of permanent magnets **30A** placed inside the slot **25**, is the N pole, the outer circumferential side of a magnetic part **50B** adjacent to the magnetic part **50A**, which is constituted of a pair of permanent magnets **30B** placed inside the slot **25**, across the groove **23** is the S pole.

As illustrated in FIG. 2, with the permanent magnets **30** placed inside the slot **25**, outer circumferential corners **25c** of the slot **25** close to the grooves **23** protrude further than outer circumferential corners **30c** of the permanent magnets **30** in the radial and circumferential directions. As a result, a gap **S** is formed between each pair of the outer circumferential corners **25c** and **30c**. The gap **S** extends along an outer-radial end surface **30s** of each of the permanent magnets **30** and a circumferential end surface **30t** on the groove **23** side of the same permanent magnet **30**. Since the gap **S** is formed between the outer circumferential corners **25c** of the slot **25** and the outer circumferential corners **30c** of the permanent magnets **30**, the outer circumferential corners **25c** and **30c** are prevented from contacting each other, preventing stress concentration caused by a centrifugal force generated by the rotating rotor.

A resin filling hole **25e** is a substantially semicircular hole in which resin is filled to secure the permanent magnet **30** by pressing it against the slot **25** from the inner radial side.

The slot **25** is substantially the same shape as the permanent magnets **30**, except for the outer circumferential corners **25c** and the resin filling holes **25e**. Since the permanent magnets **30** are positioned in the circumferential and radial directions by making the permanent magnets **30** and the slot **25** contact each other at inner circumferential corners **30d** and **25d** on the groove **23** side and outer circumferential corners **30a** and **25a** and inner circumferential corners **30b** and **25b** at the circumferentially middle area of the slot **25**, vibration of the permanent magnets **30** can be prevented while the rotor is rotating.

Each of the grooves **23** is shaped symmetrically about an imaginary line **a**, which extends in the radial direction through the circumferentially middle area, and is positioned such that, with the paired permanent magnets **30** placed inside the slot **25**, the innermost part (deepest part) is positioned closer to the inner circumference of the rotor core **20** than the outermost parts of the permanent magnets **30** and closer to outer circumference of the rotor core **20** than the inner circumferential surfaces of the permanent magnets **30**. The grooves **23** are not limited to substantially U-shaped grooves, such as those illustrated in FIGS. 1 and 2, but may be substantially semicircular, substantially V-shaped, or substantially rectangular.

Since the rotor core **20** has the gaps **S** and the grooves **23**, a circumferential rib **27a** is formed between each gap **S** and each outer circumferential surface **20s** of the rotor core **20**, a radial direction rib **27b** is formed between each gap **S** and each groove **23**, and a curved rib **27c** is provided that connects

the circumferential rib **27a** and the radial direction rib **27b**. The circumferential rib **27a** is provided at a first position **28** on an outer circumferential surface of each of the magnets. The radial direction rib **27b** is provided at a second position **29** on a circumferential direction surface of each of the magnets. By providing the circumferential rib **27a** and the radial direction rib **27b**, magnetic saturation occurs easily at the ribs **27a** and **27b**, preventing a decrease in torque due to magnetic flux shunting between adjoining opposite poles. The radial width **A** of the radial circumferential rib **27a** in the radial direction and the circumferential width **B** of the radial direction rib **27b** in the circumferential direction are set to prevent a decrease in torque caused by magnetic flux shunting between adjoining opposite poles, as well as a decrease in fatigue strength against stress caused by a centrifugal force generated by rotation. In this embodiment, the radial width **A** of the radial circumferential rib **27a** and the circumferential width **B** of the radial direction rib **27b** are substantially the same.

The rotor core **20** has a through-hole **40**, which includes first and second sub-through-holes **40A** and **40B**, penetrating the rotor core **20** in the axial direction at positions closer to the inner circumference than the magnetic parts **50**.

Consequently, the weight of the rotor core **20** can be reduced compared with the weight of a known rotor core **151**, which is illustrated in FIG. 4, and thus, reducing stress due to a centrifugal force generated by the weight of the rotor core **20**.

A reinforcement rib **41** is disposed in the circumferentially middle area of the through-hole **40** and extends in the radial direction in alignment with the circumferential center line **b** of the center rib **26**. The reinforcement rib **41** separates the through-hole **40** into the first and second sub-through-holes **40A** and **40B**, which are symmetrical about the reinforcement rib **41**. The reinforcement rib **41** is disposed substantially parallel to the center rib **26** on the inner circumferential side of the center rib **26**, such that the circumferential center line of the reinforcement rib **41** is substantially aligned with the circumferential center line **b** of the center rib **26**.

Since the center rib **26** and the reinforcement rib **41** are respectively disposed in the circumferentially middle areas of the slot **25** and the through-hole **40**, the rigidity of the rotor core **20** against tensile stress acting upon the rotor core **20** in the radial direction can be increased, compared with a rotor core **20**, such as that illustrated in FIG. 3, not including a reinforcement rib **41**. Thus, deformation of the rotor core **20** caused by tensile stress acting upon the rotor core **20** in the radial direction due to a centrifugal force generated by the permanent magnets **30** can be prevented, stress concentration at the rotor core **20** can be reduced and dispersed. In particular, there is a great effect in reducing stress generated at the outer circumferential corner **25a** and the inner circumferential corners **25b** close to the circumferentially middle areas, the outer circumferential corners **25c** close to the grooves **23**, and the resin filling holes **25e** of the slot **25** in the rotor core **20**, which is prone to stress concentration. Since the reinforcement rib **41** is disposed substantially parallel to the center rib **26** on the inner circumferential side of the center rib **26**, such that the circumferential center line **b** of the center rib **26** is substantially aligned with the circumferential center line of the reinforcement rib **41**, rigidity of the rotor core **20** can be effectively increased against tensile stress acting upon the rotor core **20** in the radial direction.

As depicted in FIGS. 2 and 3, an imaginary line **c** is shown that extends from the center axis of the rotor core and passes through the outer-radial end surface **30s** and the inner circumferential surface of permanent magnet **30**. The imaginary line



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c also passes through the innermost diameter and the outermost diameter of the permanent magnet 30, to show a distance from the center axis of the rotor core to the innermost and outermost portions of permanent magnet 30, respectively.

Each of the sub-through-hole 40A and 40B is defined by an outer-circumferential end surface 40a and an inner-circumferential end surface 40b, which are substantially parallel to the outer circumferential surface 20s of the rotor core 20; a circumferential center part 40c, which connects the ends of the end surfaces 40a and 40b close to the circumferentially middle area; and a circumferential end section 40d, which connects the ends of the end surfaces 40a and 40b close to the circumferentially outward areas.

The inner-circumferential end surface 40b extends further toward the circumferentially outward areas (toward the imaginary line a) than the outer-circumferential end surface 40a. The circumferential center part 40c defines the reinforcement rib 41 and includes a substantially arc-shaped outer circumferential corner 40e, a substantially arc-shaped inner circumferential corner 40f, and a circumferential side surface 40g, which connects the outer circumferential corner 40e and the inner circumferential corner 40f and extends in the radial direction.

The circumferential end section 40d of each sub-through-hole 40A and 40B includes a substantially arc-shaped outer circumferential depression 40h, which is depressed in the inner circumferential direction, and a substantially semi-circular inner circumference protrusion 40i, which protrudes outward in the circumferential direction (toward the imaginary line a). The width of the circumferential end section 40d between the corresponding permanent magnet 30 and the corresponding sub-through-hole 40A or 40B in the radial direction becomes larger in the direction from the circumferentially middle area to a circumferential end section of the slot 25. With this structure, the flow of the magnetic flux generated at the inner circumferential surface of a permanent magnet 30 of one of the magnetic parts 50 to the inner circumferential surface of the magnet 30 of the other magnetic part 50 across the corresponding groove 23 is not interrupted, and magnetic resistance is reduced at the rotor core 20, increasing rotary torque.

In the through-hole 40, the radius of curvature of the outer circumferential corner 40e of the circumferential center part 40c is set smaller than that of the inner circumferential corner 40f. Consequently, while the rotor is rotating, stress can be effectively reduced at the outer circumferential corner 40e, where the radial distance from the rotary shaft is large, and stress caused by a centrifugal force due to the weight of the rotor core 20 is larger.

With the rotor 10 of the rotary electric machine according to the embodiment described above, since the through-holes 40, which penetrate the rotor core 20 in the axial direction, are formed in the rotor core 20 on the inner diameter side of the magnetic parts 50, the weight of the rotor core 20 is reduced, and a predetermined rotary torque can be output at a low electric current. Since the weight of the rotor core 20 is reduced, the centrifugal force of the rotor core 20 is reduced, and the stress generated at the rotor core 20 is reduced. Accordingly, the strength of the rotor core 20 can be maintained.

In particular, since the slot 25 has the center rib 26, and the through-hole 40 has the reinforcement rib 41, which is aligned with the center line b of the center rib 26, the rigidity of the rotor core 20 against tensile stress in the outer circumferential direction due to a centrifugal force of the permanent magnets 30, is increased, and stress concentration at the rotor core 20 can be reduced and dispersed. In this way, the stress

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generated at the rotor core 20, or in particular, stress generated at the outer circumferential corner 25a and the inner circumferential corner 25b closer to the circumferentially middle area of the slot 25, the outer circumferential corner 25c on the groove 23 side, and the resin filling hole 25e can be reduced, enabling the strength of the rotor core 20 to be maintained.

With the rotor 10 of the rotary electric machine according to this embodiment, since the width of the center rib 26 in the circumferential direction is set larger than the width of the reinforcement rib 41 in the circumferential direction, magnetic saturation easily occurs at the center rib 26, reducing the magnetic flux shunting from one of the magnetic pole surfaces of the permanent magnet 30 to the other magnetic pole surface of the opposite pole, and improving the rigidity of the rotor core 20.

With the rotor 10 of the rotary electric machine according to this embodiment, since the through-hole 40 has the circumferential end section 40d, whose width in the radial direction in the direction from the corresponding permanent magnet 30 to the through-hole 40 increases in the direction from the circumferentially middle area to each circumferential end section of the slot 25, the magnetic flux generated at the permanent magnet 30 is less likely to be interrupted by the through-hole 40, and the magnetic resistance of the rotor core 20 between the slot 25 and the through-hole 40 is reduced, improving the rotary torque.

With the rotor 10 of the rotary electric machine according to this embodiment, since the outer circumferential corner 40e and the inner circumferential corner 40f of the circumferential center part 40c of the through-hole 40 are substantially arc-shaped, and the radius of curvature of the outer circumferential corner 40e is set smaller than that of the inner circumferential corner 40f, stress can be effectively reduced at the outer circumferential corner 40e, where the distance from the rotary shaft center in the radial direction is large and stress caused by a centrifugal force due to the weight of the rotor core 20 is larger.

The rotor 10 of the rotary electric machine according to the present invention is not limited to the embodiment described above, and various changes and modifications may be made appropriately.

For example, at least one rib, which extends in the radial direction and further separates each of the first and second through-holes 40A and 40B along the circumferential direction, may be disposed in the through-hole 40. In such a case, the number, position, size of the ribs are determined so that the rigidity of the rotor core 20 is improved and the weight of the rotor core 20 is reduced.

The embodiment of the present invention provides a rotor of a rotary electric machine (for example, a rotor 10 of a rotary electric machine in the embodiment) includes a rotor core (for example, a rotor core 20 in the embodiment); and a plurality of magnetic parts (for example, a magnetic part 50 in the embodiment) disposed inside the rotor core along the circumferential direction at predetermined intervals, wherein the magnetic parts are magnetized in the radial direction, and the magnetization direction of the magnetic parts alternates along the circumferential direction, each of the magnetic parts includes paired permanent magnets (for example, permanent magnets 30 in the embodiment) placed inside a slot (for example, a slot 25 in the embodiment) separated by a center rib (for example, a center rib 26 in the embodiment), a through-hole (for example, a through-hole 40 in the embodiment) penetrates the rotor core in the axial direction on the inner circumferential side of each of the magnetic parts, and a reinforcement rib (for example, a reinforcement rib 41 in the embodiment) is disposed in the through-hole and in align-

ment with a circumferential center line (for example, a circumferential center line **b** in the embodiment) of the center rib.

With the embodiment of the present invention, since the through-hole that penetrates the rotor core in the axial direction is formed on the inner circumferential side of the magnetic part, the weight of the rotor core is reduced, and a predetermined rotary torque can be output at a low electric current. Since the weight of the rotor core is reduced, the centrifugal force of the rotor core is reduced, and stress generated at the rotor core is reduced, maintaining the strength of the rotor core. Since the center rib is disposed in the slot, and the reinforcement rib is disposed in the through-hole in alignment with the circumferential center line of the center rib, the rigidity of the rotor core against tensile stress generated in the outer circumferential direction due to the centrifugal force of the permanent magnets is increased, and stress concentration is reduced and dispersed. Accordingly, the stress generated at the rotor core, or in particular, the stress generated at the corners of the slots in the rotor core can be reduced, maintaining the strength of the rotor core.

In the embodiment, the width of the reinforcement rib in the circumferential direction may be larger than the width of the center rib in the circumferential direction.

According to the embodiment, since the width of the reinforcement rib in the circumferential direction is larger than the width of the center rib in the circumferential direction, magnetic saturation easily occurs at the center rib, reducing the magnetic flux shunting from one of the magnetic pole surfaces of the permanent magnet to the other magnetic pole surface of the opposite pole, and improving the rigidity of the rotor core.

In the embodiment, a circumferential end section (for example, a circumferential end section **40d** in the embodiment) of the through-hole may be disposed so as to increase the width from one of the permanent magnets to the through-hole in the radial direction, along a direction from a circumferentially middle area of the slot to a circumferential end section of the slot.

According to the embodiment, since the through-hole has the circumferential end section, whose width in the radial direction in the direction from the corresponding permanent magnet to the through-hole increases in the direction from the circumferentially middle area to each circumferential end section of the slot, the magnetic resistance of the rotor core between the slot and the through-hole can be reduced with respect to the magnetic flux generated at the inner circumferential surface of the permanent magnets in the magnetized parts, and the rotary torque can be improved.

In the embodiment, an outer circumferential corner (for example, an outer circumferential corner **40e** in the embodiment) and an inner circumferential corner (for example, an inner circumferential corner **40f** in the embodiment) of the circumferentially middle area (for example, a circumferential center part **40c** in the embodiment) of the through-hole may be substantially arc-shaped, and the radius of curvature of the outer circumferential corner may be smaller than the radius of curvature of the inner circumferential corner.

According to the embodiment, since the radius of curvature of the outer circumferential corner may be smaller than the radius of curvature of the inner circumferential corner, the stress at the outer circumferential corner, where the distance from the rotary center in the radial direction is large, can be reduced at the outer circumferential corner receiving a large stress due to a centrifugal force.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the

appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed is:

1. A rotor of a rotary electric machine, the rotor comprising:

a rotor core comprising:

a center axis;

multiple layers of electromagnetic steel plates; and  
a plurality of slot groups adjacent to each other in a circumferential direction of the rotor core, the plurality of slot groups each comprising slots;

a plurality of magnet groups each comprising magnets provided in the slots respectively, the plurality of magnet groups being adjacent to each other in the circumferential direction such that directions of magnetic poles of the adjacent magnet groups are opposite;

a plurality of grooves each provided between adjacent slot groups of the plurality of slot groups on an outer circumferential surface of the rotor core, the plurality of grooves each having an innermost diameter which is a distance from the center axis of the rotor core to an innermost portion of each of the plurality of grooves, the innermost diameter being smaller than an outermost diameter of each of the magnets which is a distance from the center axis of the rotor core to an outermost portion of each of the magnets;

a circumferential rib provided at a first position on an outer circumferential surface of each of the magnets, the first position being closer to a pole center than to an outer circumferential corner of each of the magnets, the outer circumferential corner being located at the outer circumferential surface of each of the magnets, the circumferential rib extending from the first position in the circumferential direction while being spaced apart from the outer circumferential surface and the outer circumferential corner of each of the magnets;

a radial direction rib provided at a second position on a circumferential direction surface of each of the magnets, the second position being further radially inward than the outer circumferential corner of each of the magnets, the radial direction rib extending from the second position in a radial direction of the rotor core and between each of the grooves and the circumferential direction surface of each of the magnets while being spaced apart from the circumferential direction surface and the outer circumferential corner of each of the magnets; and

a curved rib connecting the circumferential rib and the radial direction rib, the curved rib having an inner surface and an outer surface both being curved in a circular arc shape, the circumferential rib, the curved rib, and the radial direction rib being spaced apart from the outer circumferential surface, the outer circumferential corner, and the circumferential direction surface of each of the magnets,

wherein the circumferential rib, the curved rib, and the radial direction rib are spaced apart from each of the magnets so as to create a gap, the gap separating the circumferential rib, the curved rib and the radial direction rib from the outer circumferential surface, the outer circumferential corner and the circumferential direction surface of each of the magnets.

2. The rotor of a rotary electric machine according to claim 1, wherein the circumferential rib and the radial direction rib have constant radial widths.

3. The rotor of a rotary electric machine according to claim 2, wherein the radial widths of the circumferential rib and the radial direction rib are equal to one another.

4. The rotor of a rotary electric machine according to claim 1, wherein the plurality of magnet groups each comprise a pair of magnets, and the plurality of slot groups each comprise a pair of slots accepting the pair of magnets, and wherein the pair of slots define a center rib extending in the radial direction.

5. The rotor of a rotary electric machine according to claim 1, wherein each of the grooves is approximately symmetrical about an imaginary line extending in the radial direction through a circumferentially middle area of each of the grooves.

6. The rotor of a rotary electric machine according to claim 2, wherein the plurality of magnet groups each comprise a pair of magnets, and the plurality of slot groups each comprise a pair of slots accepting the pair of magnets, and wherein the pair of slots define a center rib extending in the radial direction.

7. The rotor of a rotary electric machine according to claim 3, wherein the plurality of magnet groups each comprise a pair of magnets, and the plurality of slot groups each comprise a pair of slots accepting the pair of magnets, and wherein the pair of slots define a center rib extending in the radial direction.

8. The rotor of a rotary electric machine according to claim 2, wherein each of the grooves is approximately symmetrical about an imaginary line extending in the radial direction through a circumferentially middle area of each of the grooves.

9. The rotor of a rotary electric machine according to claim 3, wherein each of the grooves is approximately symmetrical about an imaginary line extending in the radial direction through a circumferentially middle area of each of the grooves.

10. The rotor of a rotary electric machine according to claim 4, wherein each of the grooves is approximately symmetrical about an imaginary line extending in the radial direction through a circumferentially middle area of each of the grooves.

11. The rotor of a rotary electric machine according to claim 6, wherein each of the grooves is approximately symmetrical about an imaginary line extending in the radial direction through a circumferentially middle area of each of the grooves.

12. The rotor of a rotary electric machine according to claim 7, wherein each of the grooves is approximately symmetrical about an imaginary line extending in the radial direction through a circumferentially middle area of each of the grooves.

13. The rotor of a rotary electric machine according to claim 1, wherein each of the grooves is disposed on the outer circumferential surface of the rotor core such that the radial direction rib extends in the radial direction between each of the grooves and a respective one of the magnets.

14. The rotor of a rotary electric machine according to claim 1, wherein the innermost diameter of the plurality of grooves is greater than an innermost diameter of each of the magnets which is a distance from the center axis of the rotor core to an innermost portion of each of the magnets.

15. The rotor of a rotary electric machine according to claim 1, wherein the gap forms a single, continuous space that extends between the circumferential rib and the outer circumferential surface, between the curved rib and the outer circumferential corner, and between the radial direction rib and the circumferential direction surface of each of the magnets.

16. The rotor of a rotary electric machine according to claim 1, wherein the magnets include respective second outer circumferential corners that directly contact the rotor core and do not form a gap.

17. A rotor of a rotary electric machine, the rotor comprising:

a rotor core comprising:

a center axis;

multiple layers of electromagnetic steel plates; and

a plurality of slot groups adjacent to each other in a circumferential direction of the rotor core, the plurality of slot groups each comprising slots;

a plurality of magnet groups each comprising magnets provided in the slots respectively, the plurality of magnet groups being adjacent to each other in the circumferential direction such that directions of magnetic poles of the adjacent magnet groups are opposite;

a plurality of grooves each provided between adjacent slot groups of the plurality of slot groups on an outer circumferential surface of the rotor core, the plurality of grooves each having an innermost diameter which is a distance from the center axis of the rotor core to an innermost portion of each of the plurality of grooves, the innermost diameter being greater than an innermost diameter of each of the magnets which is a distance from the center axis of the rotor core to an innermost portion of each of the magnets;

a circumferential rib provided at a first position on an outer circumferential surface of each of the magnets, the first position being closer to a pole center than to an outer circumferential corner of each of the magnets, the outer circumferential corner being located at the outer circumferential surface of each of the magnets, the circumferential rib extending from the first position in the circumferential direction;

a radial direction rib provided at a second position on a circumferential direction surface of each of the magnets, the second position being further radially inward than the outer circumferential corner each of the magnets, the radial direction rib extending from the second position in a radial direction of the rotor core and between each of the grooves and the circumferential direction surface of each of the magnets; and

a curved rib connecting the circumferential rib and the radial direction rib, the curved rib having an inner surface and an outer surface both being curved in an circular arc shape.

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